UCID-20582

ESTIMATE OF THYROID DOSES FOR DAVID A. TIMOTHY AND JUNE CARRELL FROM NEVADA TEST SITE LOCAL FALLOUT

L.R. Anspaugh
Y.C. Ng

October 28, 1985

Lawrence Livermore National Laboratory

Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

DISCLAIMER

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or the University of California, and shall not be used for advertising or product endorsement purposes.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy $ Microfiche $4.50

Page Range	Domestic Price	Page Range	Domestic Price
001-025	$ 7.00	326-350	$ 26.50
026-050	8.50	351-375	28.00
051-075	10.00	376-400	29.50
076-100	11.50	401-426	31.00
101-125	13.00	427-450	32.50
126-150	14.50	451-475	34.00
151-175	16.00	476-500	35.50
176-200	17.50	501-525	37.00
201-225	19.00	526-550	38.50
226-250	20.50	551-575	40.00
251-275	22.00	576-600	41.50
276-300	23.50	601-up[1]	
301-325	25.00		

[1]Add 1.50 for each additional 25 page increment, or portion thereof from 601 pages up.

ESTIMATE OF THYROID DOSES
FOR DAVID A. TIMOTHY AND JUNE CARRELL
FROM NEVADA TEST SITE LOCAL FALLOUT

L.R. Anspaugh
Y.C. Ng

Environmental Sciences Division
Lawrence Livermore National Laboratory
Livermore, California 94550

October 28, 1985

TABLE OF CONTENTS

ESTIMATE OF THYROID DOSES
FOR DAVID A. TIMOTHY AND JUNE CARRELL
FROM NEVADA TEST SITE LOCAL FALLOUT

ABSTRACT

David A. Timothy and June Rogers Carrell are litigants in Timothy vs US. They allege that their thyroid cancers have resulted from harm from radiation doses received as a result of local fallout from the testing of nuclear weapons at the Nevada Test Site. We have calculated a best estimate of the thyroid dose received by each litigant from external exposure and the ingestion of radionuclides with food. For David Timothy, the dose estimate is 7.8 rads. For June Carrell, it is 2.6 rads.

INTRODUCTION

David A. Timothy was born on August 21, 1948. He lived in Altonah, Utah, until 1967 when he went to St. George, Utah, to attend college. In late 1967, his thyroid was removed and found to contain a follicular carcinoma.

June Rogers Carrell was born on June 21, 1927. She moved to Upalco, Utah, in 1948. Subsequent moves were to Provo, Utah, in 1963; to St. George, Utah, in June 1968; to Monticello, Utah, in 1972; and to Roosevelt, Utah, in 1977. Sometime during the 1963 to 1965 time period, Mrs. Carrell noted that she had an enlarged thyroid and received medical treatment. Eventually, during April 1977, her thyroid was surgically removed and found to show a diffuse chronic thyroiditis of the Hashimoto type and contained multiple follicular adenomas and a papillary carcinoma.

Mr. Timothy and Mrs. Carrell are litigants in Timothy vs US and allege harm from radiation doses received as a result of local fallout from the testing of nuclear devices at the Nevada Test Site (NTS). The purpose of this report is to provide an estimate of such radiation dose received by each of these two litigants. The organ of interest in each case is the thyroid.

METHODOLOGY

FALLOUT LEVEL

Both litigants lived in areas of Utah beyond where monitors normally measured fallout with their hand-held exposure-rate meters. Therefore, our[a] previously developed methods of dose reconstruction are not applicable directly because they depend upon external gamma-exposure-rate measurements as the initial input. However, there are two alternate methods that can be used to determine the levels of fallout that occurred at such locations.

The first method depends upon current measurements. Any NTS fallout that reached these areas in Utah included long-lived radionuclides, such as ^{137}Cs and $^{239+240}$Pu, that are still present and easily measured. A problem in relating current measurements of ^{137}Cs and $^{239+240}$Pu deposition (nCi/m^2 or mCi/km^2) to material from NTS is that these radionuclides were also deposited by fallout from global[b] sources; and the amount deposited by global fallout is generally large compared to that deposited by local fallout from NTS. Fortunately, the atom or mass ratio of ^{240}Pu to ^{239}Pu is different for the two types of fallout and this provides a method of apportioning the ^{137}Cs deposition measured at a site into that due to global and NTS sources.[1,2]

Once the ^{137}Cs deposition due to local fallout from NTS is known, it is a relatively straightforward process to calculate the amount of short-lived fission products that accompanied the ^{137}Cs when it was originally deposited. For the calculation of doses from ingested radionuclides, this methodology does not allow us to determine when fallout arrived. This is important because the transport of radionuclides through foodchains varied by season; important variables are the availability of leafy vegetables for human consumption and pasture for milk cows.

---

[a]The Off-Site Radiation Exposure Review Project (ORERP) that is funded by the Department of Energy.

[b]The term "global fallout" refers to fallout that has been injected into the stratosphere and comes down to earth over several years. The primary sources of global fallout were large tests in the USSR and the Marshall Islands during the early 1960s.

Such measurements have been made in areas of Utah where the litigants lived, and the available data are provided in Table 1. Unfortunately, only one complete analysis is available for the area of interest (Duchesne is within 20 miles of both Upalco and Altonah). Here, it has been determined that 3±4 nCi/m^2 of ^{137}Cs from NTS were still present in June 1979. If we assume that the NTS fallout arrived in 1955, the amount of ^{137}Cs at that time would have been

$$(3 \pm 4)\ nCi/m^2 \times \exp(0.693\ t/T_{1/2}),$$

where t = Time of decay correction, 1979-1955 = 24 y and
$T_{1/2}$ = Radiological half-life of ^{137}Cs, 30.17 y.

The calculated deposition in 1955 is 5±7 nCi/m^2.

The second method of establishing fallout levels in the area depends upon an examination of the records of the gummed-film network.[4-8] Each station in this network exposed a gummed-film to fallout for 24 hours and then mailed the film to New York City for counting. Stations in this network were located at Ogden, Wendover, Salt Lake City, Provo, Delta, Milford, Price, Vernal, Payson, Hurricane, St. George, Cedar City, Richfield, Cove Fort, Gunnison, Leeds, Veyo, and Hanksville; but only stations at Milford, Salt Lake City and Wendover were in operation during the entire fallout period. Analysis of these data leads to the conclusion that about 30 different tests probably deposited fallout in the area. An estimate of the total ^{137}Cs deposit at time of fallout is 8 nCi/m^2 with an estimated geometric standard deviation (s_g) of 1.6 (one s_g limits of 5 and 13 nCi/m^2).[a]

Levels of NTS ^{137}Cs fallout estimated by the two methods agree well, and we have chosen to use the gummed-film data for the remainder of the calculations. Once the ^{137}Cs deposition is known, we can calculate the external gamma-exposure rate that would have been measured and also the levels of all other radionuclides in the fallout at the time by using the source-terms published by Hicks.[9,10]

---

[a]We have added an additional 0.5 nCi/m^2 deposited by SMALL BOY in 1962 after the gummed-film network had ceased operation.

EXTERNAL DOSE

External exposure is calculated by integration of the external gamma-exposure rate from time of arrival to 50 years.[a] Allowance is made for the shielding of houses or other buildings (such as schools) likely to be occupied. Information on lifestyle and type of home construction was taken from depositions and/or completed questionnaires provided by the litigants.

External dose to the thyroid is then calculated from external exposure by use of a conversion factor on the order of 0.8 rad/R.[11] Dose calculations for these two litigants were based upon previous calculations performed by the Los Alamos National Laboratory.[12]

For both David Timothy and June Carrell, our best estimate of the external dose to the thyroid is 0.32 rads with a geometric standard deviation of 1.97 (one s_g limits of 0.16 to 0.62 rads).

INTERNAL DOSE

Radiation doses from ingestion of radionuclides in food can be calculated according to the equation

$$D = \sum_i ER \cdot DEPNO_i \cdot ING_i \cdot DCON_i, \qquad (1)$$

where D = Absorbed dose, rad;

ER = External gamma-exposure rate at H + 12 h, mR/h;

$DEPNO_i$ = Normalized deposition of radionuclide i at time of arrival per unit exposure rate at H + 12 h, $\mu Ci/m^2$ per mR/h;

ING_i = Integrated intake of radionuclide i per unit deposition, μCi per $\mu Ci/m^2$; and

$DCON_i$ = Absorbed dose per unit intake of radionuclide i, rad/μCi.

This is the general method used by the Off-Site Radiation Exposure Review Project (ORERP) to calculate radiation dose to downwind residents where ER was

[a] Most of the exposure actually occurs within a few weeks.

measured at some time and normalized to H + 12 h. As explained above, we do not have measured values of ER appropriate for these litigants, but we have derived them from estimates of ^{137}Cs deposition.

Calculations of internal dose to the thyroid via ingestion were made for four radionuclides of significance. These are ^{131}I, ^{132}Te, ^{133}I, and ^{135}I.

Normalized Deposition

Values of normalized deposition were taken from the data published by Hicks.[10] We have estimated arrival times for the events of interest based upon the gummed-film data and analysis of cloud trajectories.[7,8,13-15]

Integrated Intake

The integrated intake of a radionuclide by an individual depends upon two basic factors: the agricultural system that supplies food to the individual and the individual's pattern of food consumption. Data on these factors for the two litigants were taken from depositions and questionnaires completed by them, and were supplemented with generic data where necessary.

Tabulations and calculations of these factors were based upon calculations previously performed by Kirchner[16] who also has calculated the values of integrated intake by using the PATHWAY model[17] developed by Colorado State University for the ORERP. The calculated values are provided as geometric means with an estimated geometric standard deviation of 2.0 (1.8 for food-chain transport and 1.5 for food-consumption rate).

Dose-Conversion Factors

After a radionuclide has been ingested, the amount of radiation absorbed by a target organ depends upon several factors. The more important are 1) the fraction of activity that reaches the organ of interest and other source organs, 2) the residence time of activity in the source organs, 3) the mass of the source organs, and 4) the energy absorbed in the target organ per decay of the radionuclide deposited in the source organs. Mathematical models are used to integrate these factors into a single factor referred to here as absorbed dose per unit intake with units of rad/μCi.

Such factors have been calculated and tabulated by many individuals and groups. For ^{131}I dose to the thyroid, a detailed evaluation has been done recently by Dunning and Schwarz.[18] They have concluded, after analysis of available measurements, that factors 1, 2, and 3 (above) are each distributed lognormally; and they have used a Monte Carlo approach to estimate the characteristics of distribution of the dose-conversion factor. For adults, they estimate values of 1.12, 1.37, and 0.9 rad/μCi for the geometric mean, arithmetic mean, and arithmetic standard deviation, respectively. From their tabulated data, we calculate a geometric standard deviation of 1.8, and have used this value as a reasonable estimate of each of the geometric standard deviations for the dose factors of the four radionuclides considered for the thyroid dose.

For these calculations, we have used the adult dose factors tabulated by Dunning and Schwarz for ^{131}I and those tabulated by the International Commission on Radiological Protection (ICRP)[19] for ^{132}Te, ^{133}I, and ^{135}I after converting them from arithmetic means to geometric means. Age-adjusted dose factors for infants and children were scaled from adult factors based upon age-dependent dosimetric data[20,21] and organ weights.[22]

RESULTS OF DOSE CALCULATIONS

The thyroid doses calculated for David Timothy are summarized in Table 2. Our best estimate of the total thyroid dose for David Timothy is 7.8 rads with a one s_g range of 2.8 to 22 rads.

The thyroid doses calculated for June Carrell are summarized in Table 3. Our best estimate of her total thyroid dose is 2.6 rads with a one s_g range of 0.94 to 7.0 rads.

REFERENCES

1. H. L. Beck and P. W. Krey, "Radiation Exposure in Utah from Nevada Nuclear Tests," Science 220, 18-24 (1983).

2. P. W. Krey and H. L. Beck, The Distribution Throughout Utah of ^{137}Cs and $^{239+240}Pu$ from Nevada Test Site Detonations, U.S. Department of Energy, Environmental Measurements Laboratory, New York City, NY, EML-400 (1981).

3. H. L. Beck, U.S. Department of Energy, Environmental Measurements Laboratory, New York City, NY, personal communication (1983).

4. Health and Safety Division, Radioactive Debris from Operations BUSTER and JANGLE: Observations beyond 200 Miles from the Test Site, New York Operations Office, U.S. Atomic Energy Commission, New York City, NY, NYO-1576 (1952).

5. Health and Safety Division, Radioactive Debris from Operations TUMBLER and SNAPPER: Part I, New York Operations Office, U.S. Atomic Energy Commission, New York City, NY, NYO-4505 (DEL) (1953).

6. Health and Safety Division, Radioactive Debris from Operations UPSHOT and KNOTHOLE, New York Operations Office, U.S. Atomic Energy Commission, New York City, NY, NYO-4552 (DEL) (1954).

7. R. J. List, Radioactive Debris in North America from Operation TEAPOT, New York Operations Office, U.S. Atomic Energy Commission, New York City, NY, NYO-4696 (DEL) (1956).

8. H.L. Beck, Estimates of Fallout from Nevada Weapons Testing in the Western United States Based on Gummed-Film Monitoring Data, U.S. Department of Energy, Environmental Measurements Laboratory, New York City, NY, EML-433 (1984).

9. H. G. Hicks, "Calculation of the Concentration of Any Radionuclide Deposited on the Ground by Off-Site Fallout from a Nuclear Detonation," Health Phys. 42, 585-600 (1982).

10. H. G. Hicks, Results of Calculations of External Gamma Radiation Exposure Rates from Fallout and the Related Radionuclide Compositions, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-53152 (in 8 parts) (1981).

11. T. Ashton and F. W. Spiers, "Attenuation Factors for Certain Tissues when the Body is Irradiated Omnidirectionally," Phys. Med. Biol. 24, 950-963 (1979).

12. R. F. Smale, Los Alamos National Laboratory, Los Alamos, NM, personal communication (1984).

13. P. W. Allen and L. Machta, Transport of Radioactive Debris from Operations BUSTER and JANGLE, Defense Nuclear Agency, Washington, DC, WT-308(EX) (1952).

14. R. J. List, Radioactive Debris from Operations TUMBLER and SNAPPER, Part II, New York Operations Office, U.S. Atomic Energy Commission, New York City, NY, NYO-4512 (DEL) (1953).

15. R. J. List, The Transport of Atomic Debris from Operation UPSHOT-KNOTHOLE, New York Operations Office, U.S. Atomic Energy Commission, New York City, NY, NYO-4602 (DEL) (1953).

16. T. B. Kirchner, Colorado State University, Fort Collins, CO, personal communication (1984).

17. M. D. Otis, Sensitivity and Uncertainty Analysis of the PATHWAY Radionuclide Transport Model, Colorado State University, Fort Collins, CO, Ph.D. Dissertation (1983).

18. D. E. Dunning, Jr. and G. Schwarz, "Variability of Human Thyroid Characteristics and Estimates of Dose from Ingested ^{131}I," Health Phys. 40, 661-675 (1981).

19. ICRP, Limits of Intakes of Radionuclides by Workers, International Commission on Radiological Protection, Publication 30, Parts 1, 2 and 3, Annals ICRP 2 No. 3/4 (1979); 4 No. 3/4 (1980); 6 No. 2/3 (1981).

20. G. G. Killough, D. E. Dunning, Jr., S. R. Bernard, and J. C. Pleasant, Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring in Routine Releases from Nuclear Fuel-Cycle Facilities, Vol. I, Oak Ridge National Laboratory, Oak Ridge, TN, NUREG/CR-0150, Vol. 1 (1981).

21. D. E. Dunning, Jr., S. R. Bernard, P. J. Walsh, G. G. Killough, and J. C. Pleasant, Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring in Routine Releases from Nuclear Fuel-Cycle Facilities, Vol. II, Oak Ridge National Laboratory, Oak Ridge, TN, NUREG/CR-0150, Vol. 2 (1981).

22. G. R. Hoenes and J. K. Soldat, Age-Specific Radiation Dose Commitment Factors for a One-Year Chronic Intake, Battelle Pacific Northwest Laboratories, Richland, WA, NUREG-0172 (1977).

Table 1. Total ^{137}Cs inventories and amounts apportioned to local fallout from NTS at pertinent sites in northern Utah.

	^{137}Cs inventory,[a] nCi/m^2	^{137}Cs from NTS,[a] nCi/m^2
Salt Lake City[b]	130 ± 4	15 ± 6
Duchesne[b]	85 ± 4	3 ± 4
Vernal[b]	81 ± 5	9 ± 6
N. of Altonah[c]	87 ± 4	NA[e]
Arcadia[d]	95 ± 4	NA[e]
Mountain Home[d]	83 ± 2	NA[e]
Talmage[d]	79 ± 4	NA[e]

[a]Numbers calculated are corrected for radioactive decay to June 1979.

[b]From Krey and Beck, EML-400 (1981).

[c]From Beck, personal communication (1983).

[d]Measured by the ORERP in 1983 or 1984; these results are preliminary.

[e]NA means that complete results of analyses are not yet available, so this calculation cannot be made.

Table 2. Summary of thyroid-dose estimates for David Timothy.

Pathway	Geo. mean, rad	Geo. std. dev.	Arith. mean, rad	Arith. std. dev., rad
Internal, via ingestion				
^{131}I	7.29	2.84	13.	18.
^{132}Te	0.092	2.83	0.16	0.22
^{133}I	0.10	2.83	0.18	0.25
^{135}I	0.000041	2.83	0.000071	0.000099
External	0.32	1.97	0.40	0.31
Total[a]	7.8	2.81	13.	18.

[a]Calculated by summing the arithmetic means and by calculating the arithmetic variance of the sum by adding individual variances and calculating and adding covariances; the geometric mean and geometric standard deviation were then calculated according to formulae in Ref. 18.

Table 3. Summary of thyroid-dose estimates for June Carrell.

Pathway	Geo. mean, rad	Geo. std. dev.	Arith. mean, rad	Arith. std. dev., rad
Internal, via ingestion				
^{131}I	1.95	2.84	3.4	4.7
^{132}Te	0.024	2.83	0.041	0.058
^{133}I	0.26	2.83	0.45	0.63
^{135}I	0.0028	2.83	0.0049	0.0068
External	0.32	1.97	0.40	0.31
Total[a]	2.6	2.72	4.3	5.6

[a]Calculated by summing the arithmetic means and by calculating the arithmetic variance of the sum by adding individual variances and calculating and adding covariances; the geometric mean and geometric standard deviation were then calculated according to formulae in Ref. 18.